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(54) **High strength ceramic honeycomb structure.**

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(73) Proprietor: **NGK INSULATORS, LTD.**
2-56, Suda-cho, Mizuho-ku
Nagoya-shi, Aichi 467(JP)

(72) Inventor: **Hattori, Isao**
30 Aza-Inowari, Ohaza-Fukutamaeshinden, Nanyo-cho
Minato-ku, Nagoya-City, Aichi Pref.(JP)
Inventor: **Ikeshima, Koichi**
20-3 Aza-Eukada Fukuoka-cho
Okazaki City Aichi pref.(JP)

(74) Representative: **Paget, Hugh Charles Edward et al**
MEWBURN ELLIS & CO. 2/3 Cursitor Street
London EC4A 1BQ(GB)

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D scription

This invention relates to a high strength ceramic honeycomb structure suitable for use in catalyzer carriers for purifying xhaust gases from automobile engines, or heat exchangers or deodoriz rs used in factories or homes.

Ceramic honeycomb structures have been widely used for catalyzer carriers for purifying automobile engine exhaust gases or heat exchangers. As the ceramic honeycomb structures are usually secured to insides of casings through ceramic mats or wire meshes and are used at high temperatures, strength in radial directions on side surfaces (referred to hereinafter "isostatic strength") are more important than strength in axial directions. Most of the honeycomb structures in actual use include quadrilateral, particularly square cells owing to the fact that the honeycomb structures including the quadrilateral cells are easy to be manufactured and serve to reduce pressure losses. These honeycomb structures exhibit fairly high isostatic strength in directions perpendicular to the thickness directions of the partitions walls. However, their isostatic strength in directions oblique to the partition walls is very low. Therefore, there has been a risk of the honeycomb structures being broken off in diagonal directions in casings due to thermal stresses in use or forces mechanically acting upon the honeycomb structures upon mounting in the casings.

In order to avoid such disadvantages, honeycomb structures have been proposed whose outer circumferential walls and partition walls in the proximity of the outer circumferential walls are made thicker, as disclosed in JP-A-55-142,189, JP-A-55-147,154 and JP-A-55-155,741 as shown in present Fig. 2, which is different from a conventional honeycomb structure having uniform wall thicknesses shown in present Fig. 1. However, the honeycomb structures having the partially thicker walls and partitions increase pressure losses, and what is worse still, they decrease thermal shock strength. As shown in present Fig. 3, a honeycomb structure has been also proposed, which includes fine cells in the proximity of an outer circumference JP-A-55-155,742. This honeycomb structure likewise increases the pressure losses. Moreover, the surface area in the proximity of the outer circumference at which flow of exhaust gases is low, is increased and consumes a great amount of expensive catalytic metal which is disadvantageous from an economical viewpoint. Furthermore, a honeycomb structure has been proposed whose outer circumferential surface is coated with a glazed layer to increase the strength (Japanese Laid-open Utility Model Application No. 53-133,860). However, manufacturing process for the honeycomb structure are complicated, increasing manufacturing cost. Moreover, there is difference in coefficient of thermal expansion between the glazed layer and the honeycomb structure itself, lowering the thermal shock strength of the structure.

US-A-444828 discloses honeycombe structures having inter alia square or rectangular cells at the centre and triangular cells at the periphery.

It is a principal object of the invention to provide a high is a principal object of the invention to provide a high strength ceramic honeycomb structure which eliminates or reduces disadvantages of the prior art and has a high isostatic strength preferably in all directions without excessively increasing pressure losses, and which can have low manufacturing cost and preferably has no decrease in thermal shock strength.

The invention is set out in claim 1.

With the arrangement, the partitions walls of the triangular cells directed towards the center in the zone in the proximity of the outer circumference of the honeycomb structure serve to improve the isostatic strength of the structure and to decrease the pressure losses to the minimum as shown in the following comparative tests.

In a preferred embodiment of the invention, the quadrilateral cells are square and the triangular cells are isosceles right triangular, and the partitions of the triangular cells are at substantially 45° to the partitions forming the quadrilateral cells.

In one embodiment, the area of four triangular cells is equal to that of four quadrilateral cells. Alternatively, the area of eight triangular cells may be equal to that of nine quadrilateral cells, or the area of two triangular cells may be equal to that of one quadrilateral cells, or the area of the six triangular cells may be equal to that of four quadrilateral cells.

In order that the invention may be more clearly understood, preferred embodiments will be described, by way of example, with reference to the accompanying drawings.

Fig. 1 is a front elevation illustrating a conventional honeycomb structure;

Fig. 2 is a front view showing a honeycomb structure reinforced according to the prior art;

Fig. 3 is a front view illustrating another honeycomb structure reinforced according to the prior art;

Fig. 4 is a front view showing a first embodiment of the honeycomb structure according to the invention;

Fig. 5 is a front view illustrating a second embodiment of the honeycomb structure according to the invention;

Fig. 6 is a front view illustrating a third embodim nt of the honeycomb structure according to the

invention;

Fig. 7 is a front view illustrating a fourth embodiment of the honeycomb structure according to the invention;

Fig. 8 is a front vi w showing a fifth embodiment of the honeycomb structure according to the invention; and

Fig. 9 is a front view illustrating a sixth embodiment of the honeycomb structure according to the invention.

Fig. 4 illustrates a cylindrical honeycomb structure of a first embodiment of the invention having a diameter of 100 mm and a length of 100 mm. A number of square cells 1 are arranged with a density of 400 per square inch (62 cells per cm^2). Partitions 2 constituting the square cells 1 have a thickness of approximately 0.13 mm (5mil). Triangular cells 4 having diagonal partitions 3 are arranged in a zone of a width of about 10 mm near to an outer circumference of the honeycomb structure. In this embodiment, these triangular cells 4 are provided over the entire circumference of the honeycomb structure. There are many partitions forming the triangular cells 4. Among these partitions, important partitions for improving the isostatic strength are those oblique at 45° to partitions forming the square cells and extending substantially toward the center of the honeycomb structure. Such partitions are shown by P in Fig. 4.

In the embodiment shown in Fig. 4, four triangular cells 4 having the diagonal partitions are arranged in an area corresponding to an area of four square cells 1 at the center of the honeycomb structure. Accordingly, the number ratio of the triangular cells to the square cells is 1/1. In another embodiment shown in Fig. 5, this number ratio is 8/9, while in further embodiments shown in Figs. 6 and 7, the number ratio is 2/1. On the other hand, in a particular embodiment shown in Fig. 8 which includes square cells in an outer circumferential zone, the number of ratio is 2/1. When the number ratio is increased by forming small triangular cells 4 in the outer peripheral zone, the isostatic strength is improved, but the pressure losses are increased. Therefore, within the invention, the number ratio is less than 2/1, preferably as near to 1/1 as possible. In an embodiment shown in Fig. 9, diagonal partitions 3 are provided only in directions effective to increase the isostatic strength of the structure. The number ratio is 2/1 in this case. However, the number ratio is not limited to this value. Although the honeycomb structures are circular in cross-section of the outer circumference in the embodiments above described, the invention is of course applicable to honeycomb structures elliptical in cross-section which have been widely used.

Ceramic honeycomb structures having cell densities of 100-600 cells per square inch (15-93 cells per cm^2) are widely used, in which case triangular cells can typically be arranged in widths corresponding to 4-10 square cells or 4-13 mm from outer circumferences toward centers.

In order to ascertain the effects of the present invention, comparative tests have been carried out with the honeycomb structures of the first embodiment of the present invention and those of the prior art shown in Figs. 1-3. Results of the tests are shown in Table 1. The honeycomb structures of the prior art I are those having uniform wall cells as shown in Fig. 1.

The honeycomb structures of the prior art II are those having outer circumferential walls and partitions in zones of widths of about 10 mm at the outer peripheries, thicknesses of these walls and partitions being 1.6 times those of partitions at the center as shown in Fig. 2. On the other hand, the honeycomb structures of the prior art III are those having zones of widths of about 10 mm at the outer peripheries, in which zones there are cells having densities four times those at centers of the honeycomb structures. All the honeycomb structures have diameters of 100 mm and lengths 100 mm.

Testing methods are as follows.

Isostatic strength

Aluminum plates of an about 20 mm thickness were applied to both end surfaces of each the honeycomb structure through urethane sheets of an about 0.5 mm thickness. A side surface of the honeycomb structure was sealed by an urethane tube of an approximately 0.5 mm thickness. The sealed honeycomb structure was arranged in a hydraulic vessel whose pressure was then progessively increased. Pressure was measured when breaking sound occurred in the vessel.

Table 1

		Present invention	Prior art I	Prior art II	Prior art III
Cell structure	Thickness of partition mm	0.13	0.13	0.13 0.2 (outer zone)	0.13
	Number of cell per ~~area of~~ square inch (per cm^2)	400 (62)	400 (62)	400 (62)	400 (62) 1600 (248) (outer zone)
Isostatic strength kg/cm^2		15	4	18	9
Deformation of cell		none	deformed in zone 5 mm from outer circumference	none	deformed in zon 2 mm from outer circumference
Thermal shock-resistance difference in temperature °C		850	850	788	825
Pressure loss mm H_2O		54	52	56	60
Flow rate m/sec		8.5	8.5	4.0	0.2

Thermal shock-resistance

The honeycomb structures were charged in an electric furnace whose inner temperature was maintained at temperature higher 700 °C than room temperature. Aft r the hon ycomb structures were kept in

the electric furnace for twenty minutes, the structures wer removed from the furnac and arrang d on refractory bricks so as to be cooled to the room temperature. If cracks did not occur on the structures in the cooling process, the same test was repeated with the furnace whose temperature was raised by 50° C step by step. Temperature difference was measured, which was between the room temperature and the maximum temperature at which any crack did not occur. The values in the Table are mean values of four honeycomb structures.

Pressure losses and flow rate

Air at the room temperature was forced to flow through each the honeycomb structure at 3 m^3/min and pressure difference between front and rear ends of the structure was measured. Moreover, flow rates were measured at locations spaced by 7 mm from an outer circumference of the honeycomb structure.

As can be seen from the above description, the honeycomb structure comprising triangular cells arranged in a zone in the proximity of an outer circumference of the structure and having partitions which are oblique to partitions forming the quadrilateral cells in the center of the structure and extending substantially toward a center of the structure have considerably increased isostatic strength in directions oblique to the partitions of the quadrilateral cells and decreased pressure losses in comparison with the reinforced honeycomb structures of the prior art II and III.

The ceramic honeycomb structure according to the invention enables exhaust gases to flow through outer circumferential zones of the structure at high flow rates so that the exhaust gases uniformly flow through the outer circumferential zones. Accordingly, the ceramic honeycomb structure in its entirely serves to purify the exhaust gases effectively. Moreover, thermal stresses caused by the exhaust gases do not concentrate at the center of the structure, so that the thermal shock strength is improved. Moreover, the honeycomb structure according to the invention does not give rise to high manufacturing cost because it is easily produced by extrusion. Accordingly, the honeycomb structure according to the invention is of high strength and can eliminate all the disadvantages of the prior art and very valuable for practical use.

Claims

1. A ceramic honeycomb structure having, at least at its central region as seen in transverse section, a plurality of quadrilateral cells (1) arranged adjacent to each other and having triangular cells (4) in the proximity of the outer circumference of the honeycomb structure, with partition walls oblique to th partition walls of the quadrilateral cells, characterized in that at least at four regions spaced equally around the circumference there are triangular cells (4) having partition walls directed substantially towards the center of the honeycomb structure and in that the ratio of the area of each said triangular cell to the area of each said quadrilateral cell is not less than 0.5.

2. A ceramic honeycomb structure as set forth in claim 1, wherein said quadrilateral cells (1) are square and said triangular cells (4) are isosceles right triangular, and said triangular cells have partition walls (3) at substantially 45° to the partition walls of said quadrilateral cells.

3. A ceramic honeycomb structure according to claim 1 or claim 2, wherein the ratio of the area of each said triangular cell to the area of each said quadrilateral cell is about 1.

4. A ceramic honeycomb structure as set forth in claim 3, wherein the area of four of said triangular cells (4) is substantially equal to that of four of said quadrilateral cells (1).

5. A ceramic honeycomb structure as set forth in claim 3, wherein the area of eight of said triangular cells (4) is substantially equal to that of nine of said quadrilateral cells (1).

6. A ceramic honeycomb structure as set forth in claim 1 or claim 2, wherein the area of two of said triangular cells (4) is substantially equal to that of one of said quadrilateral cells (1).

7. A ceramic honeycomb structure as set forth in claim 1 or claim 2, wherein th area of six of said triangular cells is substantially equal to that of four of said quadrilateral cells (1).

Revendications

1. Une structur de céramique en nids d'abeille ayant, du moins dans sa région centrale vue en coupe transversale, une série de cellules quadrilatérales (1) disposé s d manière adjacente les unes aux autres et ayant des cellules triangulaires (4) à proximité de la circonférence extérieure de la structure en nids d'abeille, av c des parois de séparation obliques par rapport aux parois de séparation des c llules quadrilatéral s, caractérisée en ce qu'au moins quatre zones disposées à intervalles égaux le long de la circonférence présentent des cellules triangulaires (4) ayant des parois de séparation dirigées essentiellement vers le centre de la structure en nids d'abeille et en ce que le rapport entre la surface de chaque dite cellule triangulaire et la surface de chaque dite cellule quadrilatérale n'est pas inférieur à 0,5.

2. Une structure de céramique en nids d'abeille selon la revendication 1, caractérisée en ce que lesdites cellules quadrilatérales (1) sont carrées et lesdites cellules triangulaires (4) sont des triangles rectangles isocèles et en ce que lesdites cellules triangulaires ont des parois de séparation (3) formant un angle d'essentiellement 45° par rapport aux parois de séparation desdites cellules quadrilatérales.

3. Une structure de céramique en nids d'abeille selon la revendication 1 ou 2, caractérisée en ce que le rapport entre la surface de chaque dite cellule triangulaire et la surface de chaque dite cellule quadrilatérale est d'environ 1.

4. Une structure de céramique en nids d'abeille selon la revendication 3, caractérisée en ce que la surface de quatre desdites cellules triangulaires (4) est essentiellement égale à celle de quatre desdites cellules quadrilatérales (1).

5. Une structure de céramique en nids d'abeille selon la revendication 3, caractérisée en ce que la surface de huit desdites cellules triangulaires (4) est essentiellement égale à celle de neuf desdites cellules quadrilatérales (1).

6. Une structure de céramique en nids d'abeille selon la revendication 1 ou 2, caractérisée en ce que la surface de deux desdites cellules triangulaires (4) est essentiellement égale à celle d'une desdites cellules quadrilatérales (1).

7. Une structure de céramique en nids d'abeille selon la revendication 1 ou 2, caractérisée en ce que la surface de six desdites cellules triangulaires (4) est en substance égale à celle de quatre desdites cellules quadrilatérales (1).

Patentansprüche

1. Keramische Honigwaben-Struktur, die, zumindest in ihrem mittleren Bereich im Querschnitt gesehen, eine Vielzahl von aneinandergrenzend angeordneten viereckigen Zellen (1) aufweist, und die in der Nähe der äußeren Umfangslinie der Honigwaben-Struktur dreieckige Zellen (4) aufweist, mit zu den Trennwänden der viereckigen Zellen schrägen Trennwänden, dadurch gekennzeichet, daß sich zumindest in vier Bereichen, die in gleichen Abständen entlang der Umfangslinie angeordnet sind, dreieckige Zellen (4) befinden, die Trennwände aufweisen, welche im wesentlichen zur Mitte der Honigwaben-Struktur gerichtet sind, und daß das Verhältnis zwischen der Fläche einer jeden genannten dreickigen Zelle und der Fläche einer jeden genannten viereckigen Zelle nicht weniger als 0.5 beträgt.

2. Keramische Honigwaben-Struktur nach Anspruch 1, worin die genannten viereckigen Zellen (1) quadratisch sind und die genannten dreieckigen Zellen (4) gleichschenkelige rechtwinkelige Dreiecke sind, und die genannten dreieckigen Zellen Trennwände (3) mit einem Winkel von im wesentlichen 45° zu den Trennwänden der genannten viereckigen Zellen aufweisen.

3. Keramische Honigwaben-Struktur nach Anspruch 1 oder 2, worin das Verhältnis der Fläche einer jeden genannten dreieckigen Z lle zur Fläche einer jeden genannten viereckigen Zelle etwa 1 beträgt.

4. Keramische Honigwaben-Struktur nach Anspruch 3, worin die Fläche von vier der genannten dreieckigen Z llen (4) im wesentlich mit der von vier der genannten viereckigen Zellen (1) übereinstimmt.

5. Keramische Honigwaben-Struktur nach Anspruch 3, worin die Fläche von acht der genannten dreiecki-

gen Zellen (4) im wesentliche mit der von neun der genannten viereckigen Zellen (1) übereinstimmt.

6. Keramische Honigwaben-Struktur nach Anspruch 1 oder 2, worin die Fläche von zwei der genannten dreickigen Zellen (4) im wesentlichen mit der von einer der genannten viereckigen Zellen (1) übereinstimmt.

7. Keramische Honigwaben-Struktur nach Anspruch 1 oder 2, worin die Fläche von sechs der genannten dreieckigen Zellen im wesentlichen mit der von vier der genannten viereckigen Zellen (1) übereinstimmt.

FIG. 1
PRIOR ART

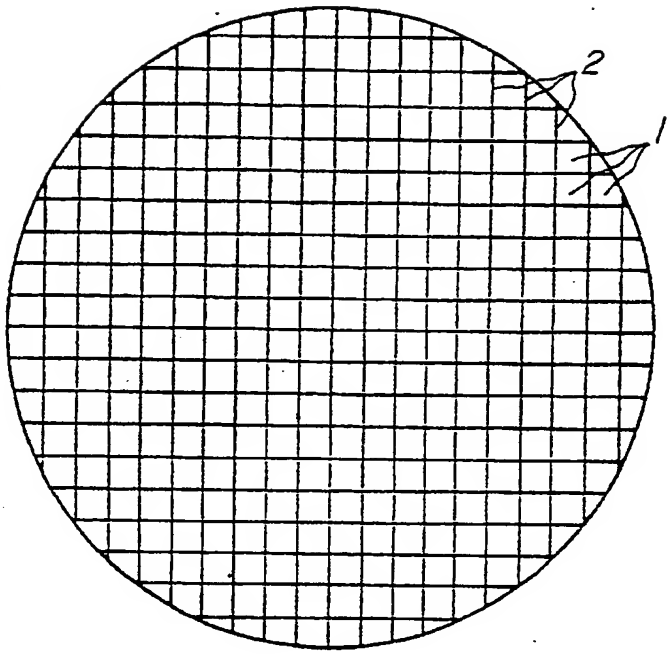

FIG. 2
PRIOR ART

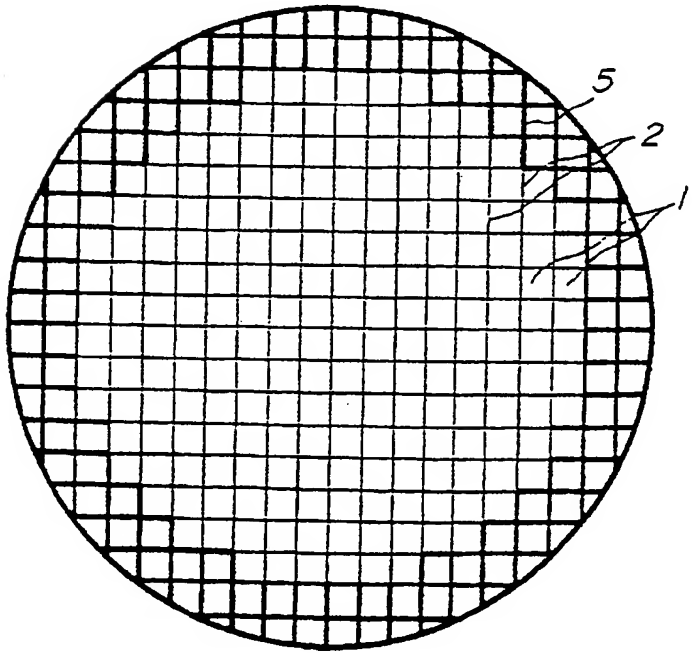

FIG_3
PRIOR ART

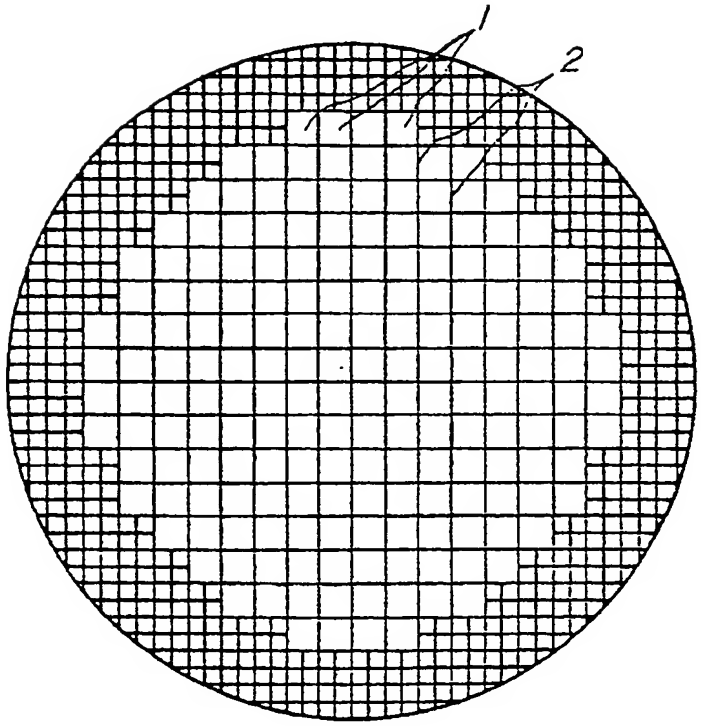

FIG_4

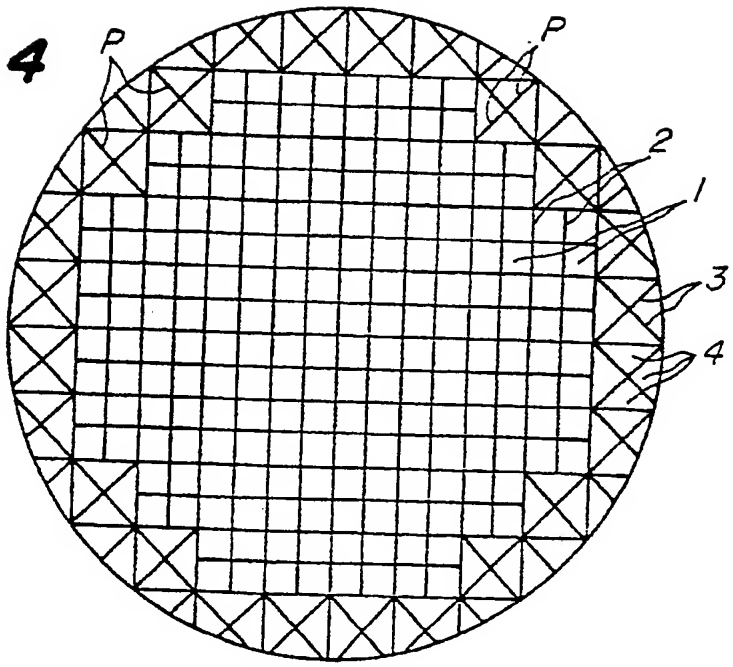

FIG_5

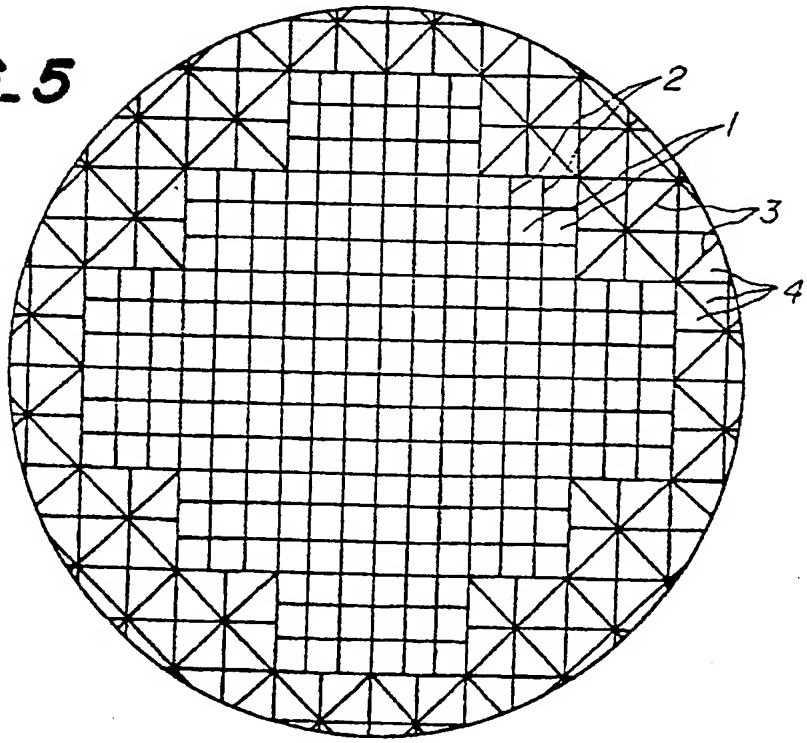

FIG_6

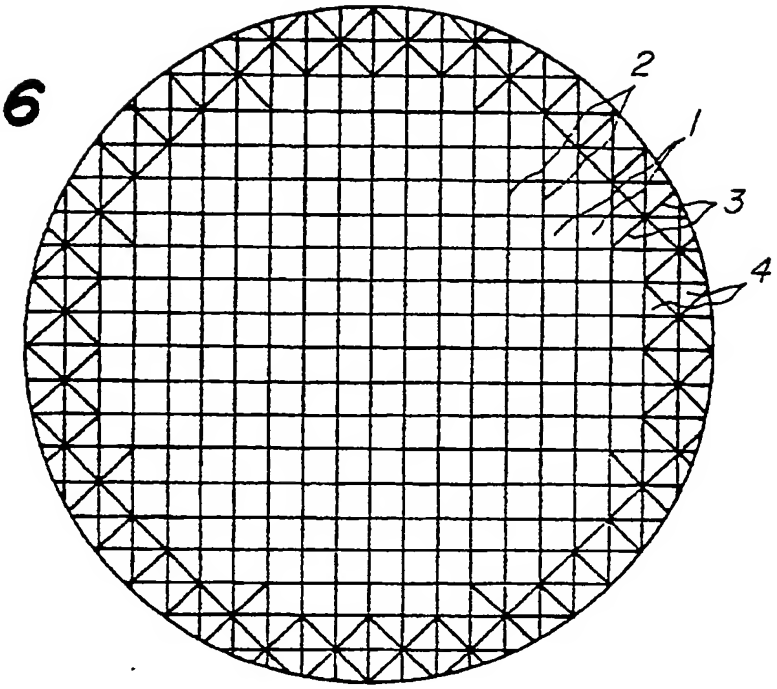

FIG_7

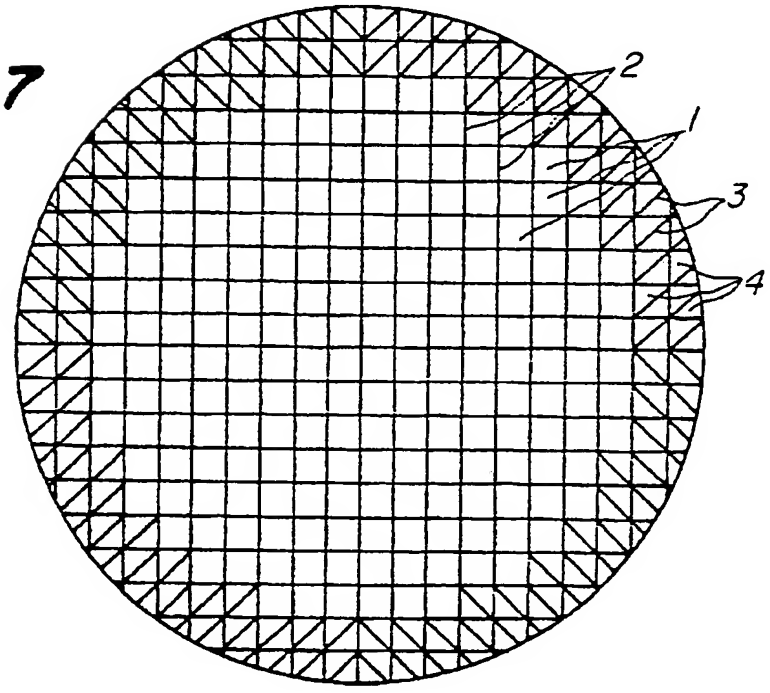

FIG_8

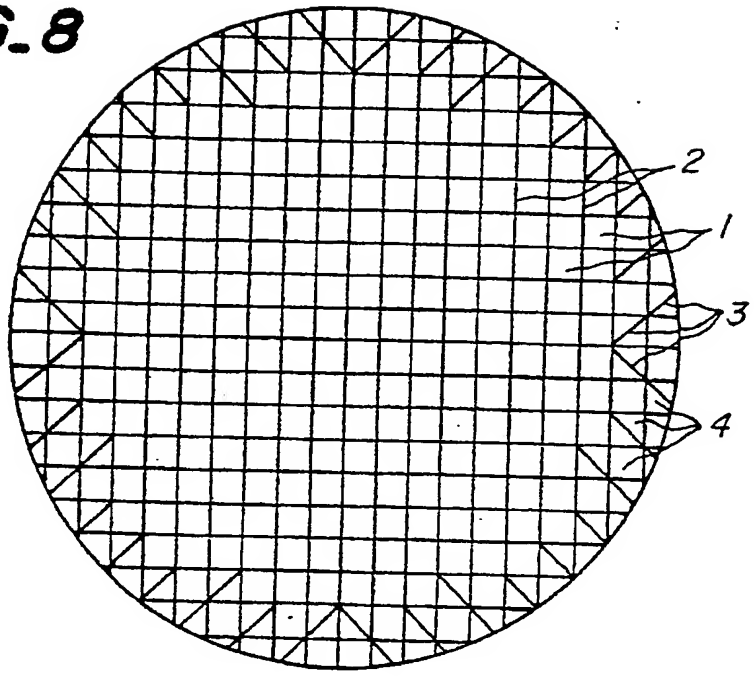
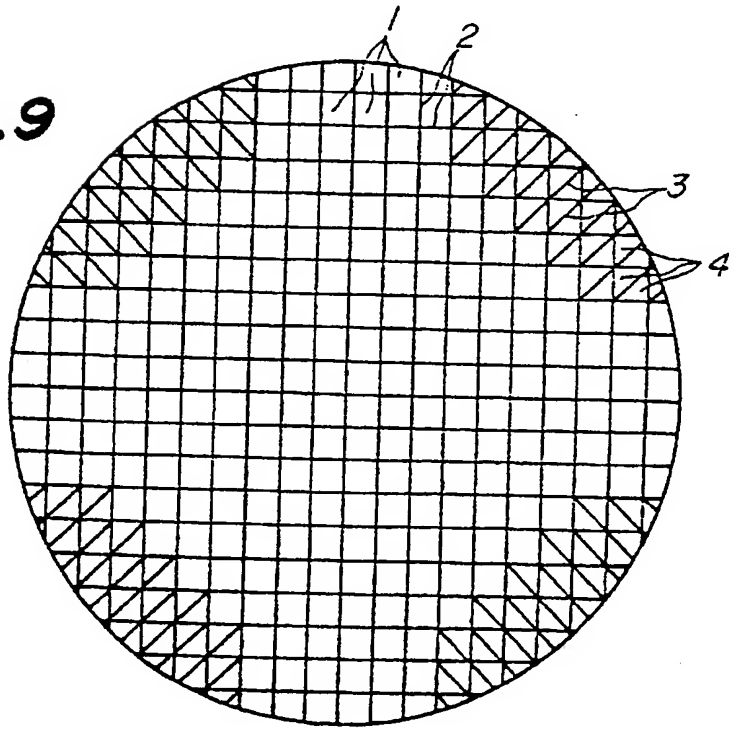
FIG_9